SEDIMENT FAN EVOLUTION AND HYDROLOGIC ACTIVITY IN MOJAVE CRATER, MARS. K. Goddard[1], S. Gupta[1], A. L. Densmore[2], J-R. Kim[4], N. H. Warner[1], P. Carbonneau[2], J-P. Muller[3]. [1]Dept. Earth Science & Engineering, Imperial College London, South Kensington Campus, SW7 2AZ, UK. [2] Durham University, Dept. Geography, Science Laboratories, DH1 3LE, UK. [3]Mullard Space Science Laboratory, University College London, Holmbury St. Mary, Surrey, RH5 6NT, UK. [4]Ziin Consulting, Seoul, South Korea.

Introduction: Sediment fan systems with well-defined catchment areas and fan surfaces with dense channel networks have been observed in Mojave crater, Mars [1]. On Earth and on Mars, such systems are as close as we can get to complete source to sink sediment routing systems [2]. They respond in complex manners to changes in hydrological conditions, tectonic subsidence and base level [2,3,4]. With careful interpretation, the geomorphology and sedimentary architecture of fan bodies can provide a record of changes in these variables over time; however, due to feedbacks and autocyclic behavior such interpretation is not simple [5].

The ~60 km Mojave crater formed no later than the Late-Hesperian epoch [1]. However, since this time period the Martian climate is thought to have been cold and dry, with surface conditions largely below the triple point of water. Thus, the presence of channeled fan surfaces in Mojave crater raises questions regarding how such features may have formed during a period that should not have supported extensive liquid water activity at the planet's surface. In addition, the precise mechanism of liquid water production at Mojave crater is poorly understood [1]. Using HiRISE image based observations, and CTX and HiRISE digital terrain models (DTM) with grid spacing of 18 m and 1 m respectively we conducted quantitive analyses of the catchment-fan geomorphology in order to constrain possible mechanisms of water availability, and determine the evolution of the systems over time.

Methods: We conducted: (1) Mapping and geomorphological analysis of fan systems using visualization of a HiRISE DTM. The HiRISE DTM was constructed from stereopair images PSP_002167_1880 and PSP_ 001481_1875. (2) Analysis of morphometric properties between catchment-fan systems, and comparisons to terrestrial and Martian studies. (3) Flow routing and watershed delineation using ArcHydro Tools, and extraction of longest flow path profiles. (4) Volume estimation of the fan deposits based upon GIS analysis of the likely eroded sediment volume from the catchments.

Results and interpretation: Based upon the locations of the fans' source areas we can categorize systems into two types: range-derived fans (emanating from catchments contained within the montane ranges that form the "inner ring" complex crater structure), and intermontane basin-derived fans (emanating from the low-lying topography between ranges which contains high-albedo fine grained sediments, possibly of impact melt origin [6]). Here we report our most important findings regarding 17 range-derived fans, and 2 intermontane basin-derived fans.

Geomorphologic observations. Range-derived systems have proximal, near-apex, surfaces that are characterized by fingers of fan sediments which extend upstream into the lower catchments, between bedrock outcrops. This indicates that as fan building progressed, localized topography at the range-front was buried. This is explained by the concept of "accommodation space": the volume available to be filled at the range front, controlled by changing subsidence, uplift or base level [7]. In Mojave this space is finite as there was likely no basin subsidence during fan building. If we assume that the slope of the fan is set to a particular range by depositional processes, then if the fan extended in length, its apex must also move higher into the catchment. Importantly, as the apex increases in height, the catchment must shrink, possibly leading to decreased fan building rates over time.

Unlike the range-derived fans, the intermontane basin-derived fan surfaces show some evidence of multiple cycles of incision and deposition (Fig. 1).

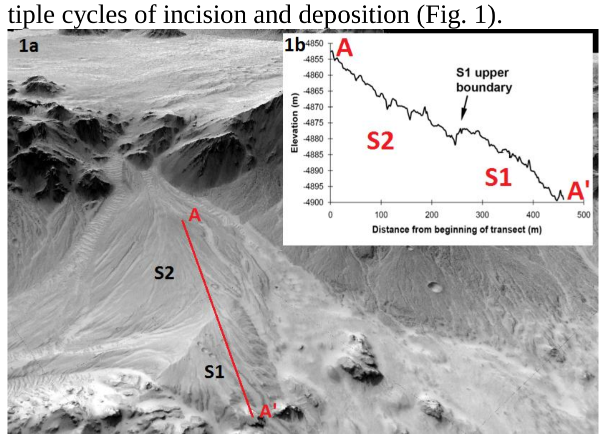

Fig. 1a. S1 is the stratigraphically oldest fan surface (visible), and is topographically higher than neighbouring S2 fan deposits. Following S1 deposition, an incision event caused S1 to become a remnant. S2 was then deposited, onlapping the remnant. *Fig. 1b.* Profile of transect (A-A') across S1 and S2 showing non continuous topography.

Morphometric properties. For 17 range-derived fans we see a strong positive correlation (R^2=0.8) between fan area and catchment area when plotted on a log-log scatter plot (refer to Fig. 2). Terrestrial and martian catchment-fan systems often display this positive relationship [3,8]. We found that Mojave systems have a high fan area with respect to catchment area, when compared with most terrestrial fans. Mojave systems show a relationship that is most equivalent to terrestrial fans found in areas with low tectonic subsidence. This reflects the fact that vertical accommodation space is limited, so fans must spread out more in plan view.

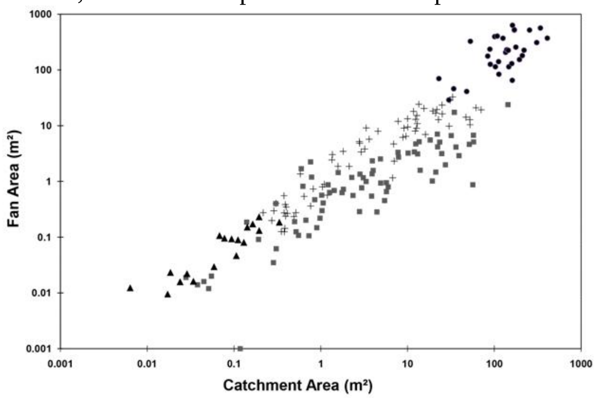

Fig. 2. Log-log plot showing catchment area plotted against fan area. Triangles = Mojave fans; grey squares = terrestrial high subsidence fans in [3]; crosses = terrestrial low subsidence fans in [3]; and circles = large Martian fans in [8].

Topographic profiles through the catchment-fan systems. Fig. 3 shows that the long profiles through the fans catchments are often of convex morphology, especially in the highest portion of the catchment. From terrestrial studies we know that convexity usually indicates the hillslope domain of the catchment. In contrast, predictable concavity of a system usually occurs when the contributing area is constantly increasing, and can indicate that a tributary network was in operation. We suggest that these catchment profiles are evidence that discrete flow events as opposed to distributed flows were responsible for the building of the fan features; channels could have been formed from one off, or infrequent, flow events rather than forming part of a frequently reactivated system. In addition, Fig. 3 shows that there is continuation of slope between the lowermost catchment section, and the fan surface. This feature has also been noted on Earth fans [2]. It is suggested that this indicates that the generation of fan slopes is driven by the balance of erosion within the catchment, rather than purely by fan depositional processes [9].

Volume analysis. Our catchment volume estimation method is likely to provide a low constraint on potential fan volumes, due to the fact that the topography of the catchment rim was probably once higher, prior to erosion. Bearing in mind this caveat, we show that the 11 catchment volumes analysed so far show values ranging from ~200,000 m^3 to ~1800,000 m^3, correlating to mean fan thicknesses in the range of ~1 to 20 m. We aim to refine this method in the future.

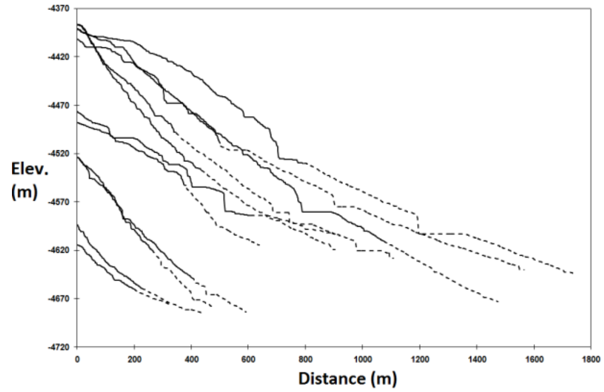

Fig. 3. Topographic profiles along the longest flow paths through range-derived catchments-fan systems, constructed using Arc-Hydro Tools. Solid line = catchment, dotted line = fan surface.

Conclusion: In this study we present new ideas regarding catchment-fan system evolution and past water activity in Mojave crater.

- We have observed geomorphologic features of multiple episodes of incision and deposition on intermontane basin-derived fans, indicating that water activity may have been episodic.
- Range-derived fans show evidence of sediment backfilling into catchments. This suggests that catchments may have shrunk over time, reducing fan building rates; it is possible that the systems may have been self limiting due to this negative feedback.
- Catchment topographic profiles are largely of convex morphology. We suggest that this could be evidence that discrete flow events, as opposed to distributed flows, were responsible for fan building.
- Although probably a low estimate, our volume analysis shows that mean fan thicknesses are likely to be relatively small, from ~1 – 20 m.

References: [1] Williams R. M. E and Malin M. C. (2008), *Icarus*, 198(2), 365-383. [2] Densmore A. L. et al. (2007) *JGR*, 112. [3] Allen and Hovius, 1998], [4] Blissenbach E. (*1954), GSA Bulletin*, 65(2), 175-190. [5] Clarke L. T. et al. (2009). *Geomorphology*, 115(3-4), 278-285. [6] Tornabene. L. et al. (2007), *7th Int. Conf. on Mars*, *LPI*, 1353. [7] Viseras C. et al. (2003). *Geomorphology,* 50, 1-3. [8] Moore J. M and Howard A. D. (2005), *JGR*, 110. [9] Bull W.B. (1964) *GSPP*, 437(A), 1-71. [10] Garvin J. B. et al. (2003), *6th Int. Conf. Mars,* Abstract #2377.